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DEPT. OF EDUCATION
HISTORICAL COLLECTION

BIOLOGY

grade 13

EDUCATIONAL TELEVISION SERIES 1967-68

Educational Television Branch
ONTARIO DEPARTMENT OF EDUCATION
1670 Bayview Avenue/Toronto 17

program schedule

BIOLOGY
grade 13

26 programs of 30 minutes each

PROGRAM NO.	CBC 10:00	CBOT 10:00	CHCH 9:30	CJOH CJSS 9:30
1	Oct. 21	Same as CBC	Oct. 28	Jan. 6
2	Oct. 28	" "	Nov. 4	Jan. 13
3	Nov. 4	" "	Nov. 11	Jan. 20
4	Nov. 11	" "	Nov. 18	Jan. 27
5	Nov. 25	" "	Nov. 25	Feb. 3
6	Dec. 9	" "	Dec. 2	Feb. 10
7	Dec. 16	" "	Dec. 9	Feb. 17
8	Jan. 6	" "	Dec. 16	Feb. 24
9	Jan. 13	" "	Jan. 6	Mar. 2
10	Jan. 20	" "	Jan. 13	Mar. 9
11	Jan. 27	" "	Jan. 20	Mar. 16
12	Feb. 3	" "	Jan. 27	Mar. 23
13	Feb. 10	" "	Feb. 3	Mar. 30
14	Feb. 17	" "	Feb. 10	Apr. 6
15	Feb. 24	" "	Feb. 17	Apr. 13
16	Mar. 2	" "	Feb. 24	Apr. 20
17	Mar. 9	" "	Mar. 2	Apr. 27
18	Mar. 30	" "	Mar. 9	May 4
19	Apr. 6	" "	Mar. 30	May 11
20	Apr. 13	" "	Apr. 6	May 18
21	Apr. 20	" "	Apr. 13	May 25
22	Apr. 27	" "	Apr. 20	June 1
23	May 4	" "	Apr. 27	
24	May 11	" "	May 4	
25	May 18	" "	May 11	
26	May 25	" "	May 18	

BIOLOGY

A series of 26 programs of 30 minutes each
for students in grade 13

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This series was prepared and written by:
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Produced by:
PAUL FRITZ-NEMETH

general introduction

This series of twenty-six programs is intended for viewing by grade 13 students and their teachers. The programs have been planned to supplement some of the major topics contained in Curriculum S. 17B.

It is quite impossible, in the time available, to deal with every topic in a curriculum that is virtually a survey of many of the most important fields of biology. The programs that are being presented therefore represent only a selection from among the dozens of topics that could have been used. Some have been chosen because they illustrate biological principles of fundamental importance, some because of their suitability for film and television presentation, others to aid teachers in their presentation of topics that are new to the secondary school biology program. The inclusion of a particular topic in the series is not meant to indicate that it is any more important than another topic which has been omitted. It would be possible to construct several such program series of equal significance without duplicating any of the topics presently included.

The programs are intended to complement the classroom instruction. In most cases, the pace of delivery is such that the maximum benefit will be obtained by students already having some familiarity with the topic. The teacher who wishes to incorporate this series into his teaching should therefore schedule classroom instruction and reading assignments accordingly. Since not all teachers will wish to follow the order of presentation adopted in the telecast schedule, each program is complete in itself and can be viewed with advantage at any time during the year. A significant innovation in this series is that each program has been produced in 16 mm. colour film. After the initial televised presentation, these films will be available on an individual basis for classroom showing at times convenient to teachers.

One of the objectives of this series is to bring to the student experiences which are difficult to duplicate in the classroom. One such experience is that of contact with prominent scientists working in their respective fields, and a number of programs include interviews with such people.

The general purpose of the series is to stimulate an interest in biology, to help clarify important principles and to present a picture of contemporary biology.

SPECIAL NOTE REGARDING COLOUR FILM:

It is not anticipated that any prints for classroom distribution will be available in the 1967-68 school year.

program one

WHAT IS BIOLOGY?

This program is primarily a general introduction to the series.

It states first that the series is about biology and then poses the question, "What is biology?" One suggested way to find out is by talking to a number of professional biologists.

There follows a series of short interviews with a number of biologists. Each explains briefly something about the work he does and shows some of the specimens or apparatus he uses.

It is then pointed out that although they work in widely different fields, all are concerned in one way or another with living things. The question is then asked, "What are living things?" This is answered pictorially by seeing a large number of living things, chosen to illustrate their immense diversity.

After this brief survey, the final question is asked, "How do we recognize a living thing?" The program concludes with a discussion, illustrated with animation, of the characteristics of living things and the differences between the living and the non-living.

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program two

WHAT DOES CHEMISTRY HAVE TO DO WITH BIOLOGY?

LIFE PROCESSES BASED ON CHEMICAL INTERACTIONS

Living matter, like all matter, is composed of atoms and molecules. All life processes are based on chemical interactions within the cells. In order to understand living things, which is the purpose of biology, we must understand the chemical changes which are the basis of life. For this reason the emphasis in modern biology is more and more towards molecular biology. It is impossible to give an adequate picture of what modern biology has become, or other than a superficial understanding of such vital topics as respiration, photosynthesis, reproduction and inheritance, without dealing with the discoveries that have been made at the molecular level. The general purpose of this second program is therefore to illustrate the theme that chemistry is no alien intruder in the field of biology, but is absolutely essential to the solution of many fundamental biological problems.

The program begins with shots of a laboratory that seems to be full of chemical apparatus. It is then pointed out that although the operations being carried out are chemical in nature, the research being done is biological. The suggestion is made that the case of proteins be examined to illustrate how a detailed knowledge of the chemistry of proteins has helped in the solution of some difficult biological problems.

A few of the general principles of protein chemistry are then introduced, one of which is that proteins are constructed of polypeptide chains consisting of amino acids linked together. To illustrate the contention that it may be quite important to know which amino acids are present in the chains and the order in which they appear, the case of

sickle-cell anemia is introduced. The haemoglobin of sickle-cell anemia differs from normal haemoglobin in that, of the five-hundred and seventy-four amino-acid residues in the molecule, two are different. The ability of people with sickle-cell anemia to withstand malaria is referred to.

The question is then raised whether it is important to know the shape of the protein molecules as well as the amino acid sequence in its polypeptide chains.

VITAL ROLE OF ENZYMES

Reference is made to the vital role of enzymes and to enzyme specificity and to the idea that their action can only be understood if we know the exact shape of the enzyme molecule.

The remainder of the program consists of an interview with Dr. A. C. T. North of Oxford University. Dr. North was a member of the research team led by Dr. D. C. Phillips at the Royal Institution in London that unravelled the three-dimensional structure of the enzyme lysozyme and the complex it forms with its substrate. This is the antibacterial agent of tears.

Dr. North shows how X-ray diffraction patterns of the lysozyme crystal are obtained, how measurements made from these patterns are fed into an electronic computer so that electron density contours of the crystal can be obtained, and how these contour maps are used to deduce the structure of the lysozyme molecule.

He then shows a giant three-dimensional model of the molecule and explains why the polypeptide chains have folded up as they do. He finishes by showing how the enzyme combines with its substrate, a carbohydrate forming part of the wall of the bacterial cell, explaining how this breaks down the wall and leads to the destruction of the cell.

The program concludes with a brief re-statement of the theme that the solution to many basic biological problems lies in an understanding of the molecular processes upon which life is based.

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program three

LOOKING AT CELLS—PART I

FIRST CELLS FORMED FROM ORGANIC MATERIALS

With the establishment in program two of the need for some knowledge of the chemistry of living things, the necessary chemical background can be presented. One of the best ways of doing this is by an introduction to the work on the cell. If the origin of the earth is briefly considered, and the nature of its first atmosphere and the chemical reactions that occured in it is discussed, it will be possible to present all the necessary background information about organic functional groups and the biologically important materials within the context of a gradually unfolding evolutionary story. As the culmination of this onward-moving story line, there can be a discussion of how the first living cells could have been formed from the rich mixture of organic materials in the ancient oceans.

The program begins with a historical survey that charts some of the main points in the gradual development of the cell doctrine and shows how these were related to technical advances in the art of microscopy.

It then proceeds to a consideration of the structure of cells, plant and animal, as revealed by light microscopy.

It concludes with a visit to a histological laboratory to see how tissues are prepared for microscopic study.

As a post-viewing activity, students could be asked to find out more about some of the important figures in the history of microscopy who are introduced in the program, (Jansen, Leuwenhoek, Hooke, Malpighi, Grew, Mirbel, Lamarck, von Meyen, Schleiden, Schwann).

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program four

LOOKING AT CELLS—PART II

ELECTRON MICROSCOPY

The general purpose of program four is to explain the fine structure of the cell as revealed by electron microscopy. It continues the theme established in the previous program of the dependence of discovery on technological advance.

The program begins by considering briefly the physical principles upon which the operation of the electron microscope is based and why it can reveal much finer structure than the light microscope.

This is followed by a short description of the methods used to prepare material for observation in the electron microscope. This sequence was shot in the laboratory of Dr. Allen Bell at the Marine Research Station, Wood's Hole, Massachusetts.

Most of the program is devoted to an interview with Dr. Keith Porter of Harvard University, a foremost authority on the fine structure of cells. Dr. Porter explains, by reference to his own electron-micrographs, the general architecture of the cell and its organelles.

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program five

THE MEMBRANE OF THE CELL

STRUCTURAL DETAIL

After obtaining a general picture of the cell as revealed by both light and electron microscopy, it is necessary to examine in greater detail the cellular organelles and the processes that occur within them.

The purpose of the fifth program is to consider the membrane system of the cell, especially the plasma membrane, and how materials pass through this membrane into and out of the cell.

The processes of phagocytosis and pinocytosis are illustrated, both in actuality and in animation. It is then pointed out that even when materials have been absorbed into food vacuoles or microvacuoles it is not in the physiological sense within the cell, since the unit membrane still separates the contents of the vacuole from the cytoplasm proper.

MOVEMENT WITHIN CELL

The means by which materials can pass through the membrane are then considered. The first of these is simple diffusion. The principles governing the diffusion of dissolved solutes through semi-permeable membranes are developed by means of animation. The diffusion into the cell of water by osmosis is then considered and reference is made to the means by which cells can control this movement by means of the synthesis and hydrolysis of macromolecules.

It is then pointed out that movement across the membranes of living cells cannot always be accounted for on purely physical principles and the idea of active transport is introduced. A short interview with Dr. Jack Dainty of the University of East Anglia follows in which he discusses the evidence for active transport, why the term "active" is employed, and some of the current hypotheses concerning the mechanism of active transport in plants.

It is then pointed out that in order to understand some of the processes that occur at the membrane we must know something of its structure. Dr. W. Thompson, a biochemist at the University of Toronto whose research is in the field of membrane structure, concludes the program with a short interview in which he discusses this question.

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program six

RESPIRATION I—THE OVERALL PICTURE

Having considered the membrane and how materials pass through the membrane into the cell, we continue by discussing some of the vital processes that occur within the cell. Of these respiration is one of the most important. The cell, as we have seen earlier, is a highly organized structure and this organization cannot be maintained without the continual expenditure of energy. It is the role of respiration to make this energy available in a form useful to the cell.

CHEMICAL PROCESSES INVOLVED

The program opens by considering the necessity that all living things have for energy. A discussion of the nature of chemical potential energy follows and analogies are drawn between it and other forms of potential energy. The idea of foods as sources of materials with relatively high chemical potential energy is introduced. The question of what form of energy is of most use to the cell is discussed. It is pointed out that the work of the cell is chemical work and therefore the kind of energy the cell requires is chemical potential energy. The object of respiration therefore is not to convert the chemical energy of foods into other forms of energy but to repackage it in smaller, more reactive and less wasteful parcels. Consideration is then given to the role of the

phosphagens and ATP as the vehicles by which the chemical energy of foods is repackaged and transferred in the cell to materials that must be lifted higher on the potential energy scale before they can react and perform the cell's work.

CELLULAR BREAKDOWN OF GLUCOSE

The respiratory process is then placed within its overall context in the body and its dependence on circulation and gas exchange made evident.

Taking glucose as an example of a typical food, the various stages of its breakdown within the cell are explained. The chemical events in glycolysis, acetyl co-enzyme "A" formation, and the Krebs Cycle are briefly described. The role of the respiratory chain is referred to.

The program concludes by considering the overall efficiency of the process in terms of the percentage of chemical potential energy of the glucose molecule that is actually repackaged into ATP.

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program seven

RESPIRATION II—THE MITOCHONDRION AND THE RESPIRATORY CHAIN

CLOSER LOOK AT RESPIRATORY CHAIN

In program six an overall picture of respiration was presented, its significance, and the chemical events that accompany the repackaging of the chemical potential energy of the materials that undergo respiration. Only passing reference was made to the role of the respiratory chain.

Program seven takes a closer look at the respiratory chain, its role in the uptake of oxygen, the production of ATP, and the removal and transfer of hydrogen from the respiratory substrates. The whole is approached from a historical point of view, as a kind of biochemical jig-saw puzzle, and the role of men like Warburg and Thunberg in fitting these pieces together in the correct sequence is illustrated.

WHY OXYGEN?

The program begins by considering the necessity of oxygen in the higher organisms and asks the question, "Why is oxygen needed?". Experimental proof that oxygen is used to combine with hydrogen removed from the respiratory substrates is offered. The question is then posed, "Where in the organism is oxygen actually used?". The operation of the Warburg apparatus is explained as a means of detecting oxygen uptake. It is then shown that the tissues themselves take up oxygen as well as the entire organism. The tissues are then homogenized and it is shown that the cell suspensions so produced also respire. The cell suspension is then further homogenized and then centrifuged so that the mitochondria are separated from the other components of the cell. It is shown that these organelles, if supplied with pyruvic or lactic acid, will respire just as the intact cells. The mitochondria are thus identified as the sites within the cell of aerobic respiration.

HYDROGEN REMOVAL

The question is next raised, "Where is hydrogen removed?". Evidence is offered to show that this too occurs in the mitochondria, and the research of Thunberg is referred to. The dehydrogenase enzymes are discussed. Warburg, and his idea that there must be a "respiratory enzyme" catalyzing the combination of oxygen with the hydrogen removed by the dehydrogenase systems, is then introduced, together with his discovery that this must be iron porphyrin compound. Keilin's work in proving that there are really several iron porphyrins or "cytochromes" involved in respiration is alluded to, and, in animation, the way in which they function in electron transfer is explained.

Warburg's discovery of the "yellow enzyme" or FAD is then discussed and it is shown how this acts as a bridge between the cytochrome and the dehydrogenase systems.

The complete respiratory chain is thus built up. The fact that ATP is produced as the hydrogen and its electrons pass down the respiratory is discussed.

The program concludes by showing the importance of the correct spatial organization of the components of the respiratory chain without the mitochondria.

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program eight

RESPIRATION III—ATP, THE CELL'S ENERGY CURRENCY

In the two preceding programs it was shown that a large part of the chemical potential energy of substrates undergoing respiration, is repackaged in the form of ATP.

Program eight considers in greater detail the nature of ATP and the precise way in which it functions as an energy transfer substance.

ATP IN RESPIRATION

After a general introduction in which the production ATP in respiration is briefly reviewed, the point is made that the ATP molecule has greater chemical potential energy than the ADP and inorganic phosphate from which it was made and that this extra energy must have come from the molecules undergoing respiration.

BOND ENERGY

The concept of "bond energy" is then discussed and illustrated with reference to the build-up of ATP from its components. The terms "high" and "low" energy bonds are considered.

The transfer of bond energy to ADP to form ATP in the course of respiration is then discussed and illustrated.

ATP USED IN THE CELL

Having considered the formation of ATP, the program continues with a discussion of how ATP is used or "spent" in the cell. The task of uniting a free glucose molecule to the end of a polysaccharide chain, as must occur in the synthesis of glycogen or starch, is introduced as typical of the chemical "work" the cell is called upon to perform. The role of ATP in transferring bond energy to the glucose is carefully explained as well as the reasons why this transfer must occur.

We then see demonstrations of the role of ATP in doing other kinds of cellular work, the contraction of muscle fibres and the luminescence of fireflies.

The program ends with a general discussion of energy transfer mechanism in cells.

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program nine

PHOTOSYNTHESIS, ENERGY FROM THE SUN

The first organisms that emerged from the complex mixtures of organic materials in the ancient seas were heterotrophes, obtaining energy from the organic materials around them by means of respiration. These materials were limited in amount however, since the conditions under which they could be formed were disappearing as the atmosphere changed irreversibly from a reducing to an oxidizing nature. Life could not therefore have advanced far unless some alternative source of energy became available. The alternative method of obtaining energy that eventually evolved was photosynthesis. Using systems such as the respiratory chain, that were already beginning to evolve in heterotrophic cells, methods were found of trapping or fixing the radiant energy of the sun and using it for the production of ATP and for the synthesis of high energy organic materials from simple inorganic materials in the environment.

MECHANISMS IN PHOTOSYNTHESIS

Program nine is a general description of mechanisms involved in photosynthesis, looked at from the cellular and molecular point of view.

The program begins by a discussion of the points made in the opening paragraph above. It goes on to show that radiant energy can bring about chemical change. The way in which radiant energy interacts with matter is then demonstrated using animation to show the activation of electrons.

Chlorophyll is introduced as a substance able to absorb certain frequencies of radiant energy. The isolation of the plant pigments and their absorbtion spectra are shown.

The idea is presented of utilizing a respiratory chain type arrangement of electron carriers to remove high energy activated electrons from the chlorophyll molecule. The energy from these electrons, as they pass down the chain, can be used for the production of ATP. The process of cyclical photophosphorylation is then shown in animation.

CARBON DIOXIDE BUILD UP

The program then turns to a consideration of the way in which carbon dioxide is built up into phosphoglyceraldehyde. The necessity for ATP is pointed out. The details of carbon dioxide fixation and the Calvin cycle are then briefly shown by means of animated reactions.

One factor that is made to emerge from the preceding discussion of carbon dioxide fixation, is the necessity of some form of reactive hydrogen for the reduction step. The final part of the program deals with the means by which radiant energy is harnessed to bring about the decomposition of water and thus supply the necessary hydrogen.

program ten

MITOSIS, THE REPRODUCTION OF CELLS

The ability to reproduce is the most important characteristic of living things. This being so we can consider the history of life to have begun at the moment when the first self-duplicating structure was created. This was presumably some sort of nucleic acid molecule. There was from the beginning a competition among different types of nucleic acid molecules for the materials from which they could replicate themselves and hence a kind of natural selection. This natural selection lead to the evolution of the cell as a capsule permitting the more efficient duplication of nucleic acid molecule, and of the evolution of the cellular processes that have been discussed in previous programs, as the necessary means of maintaining and holding together this capsule. The duplication of the nucleic acid within the cell, followed by the division of the cell itself, is thus the central culminating process in the life of the cell.

CELL DIVISION

Program number ten is designed to give a general picture of cell division and its significance.

The bulk of the program is devoted to a systematic description of mitosis, phase by phase. Interspersed between shots of living cells passing through the various phases of mitosis, are animated sequences and micrographs of fixed and stained material. The latter are included so that students can relate what they see in their own laboratory periods to the animation and the sequences showing living cells. The differences between plant and animal mitosis are pointed out.

The program concludes by dwelling on the significance of the duplication and splitting of the chromosones that occur in mitosis, and points out that one of the components of the chromosones, the nucleic acid, must act as the carrier of genetic information from one generation to the next.

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program eleven

DNA, THE SELF-DUPLICATING MOLECULE

The reproduction of individual cells, and hence of the entire organism, since it is composed of cells, is based on cell division. But the external changes we see in dividing cells are really only the outward reflection of a molecular event that has already occured in the cell. This is the replication of the nucleic acid, the DNA, in the nucleus of the cell. If the first living thing was some sort of DNA molecule and the cell and even the entire organism are the devices that have been evolved through natural selection to ensure the replication of DNA, then this process must be of fundamental importance.

STRUCTURE OF DNA

Program eleven deals with the structure of DNA, particularly from the point of view of how we have found out what that structure is, and how this unique structure permits the DNA molecule to replicate itself.

It begins by describing the discovery of the nucleic acids and the histochemical technique that show DNA to be a universal constituent of cell nuclei. The significance of DNA as a carrier of genetic information is discussed and the technique of isolating DNA from cells is shown.

The results of the chemical analysis of DNA are presented and the way in which its components are assembled into giant polynucleotide chains is shown. The program then turns to the problem of inferring the three-dimensional structure of the DNA molecule. A simple example is introduced to show how X-ray diffraction patterns permit the deduction of interatomic dimensions.

An interview with Dr. Watson Fuller of the University of London then follows. Dr. Fuller was a member of the team of crystallographers who gathered the data from which the Watson-Crick model of DNA was evolved. In his laboratory at King's College, Dr. Fuller shows how the X-ray diffraction work was done and outlines the process that must be gone through in order to derive the model. He concludes by describing the structure of the DNA molecule as it finally emerged.

HYDROGEN BONDING

The program continues with a consideration of the idea of hydrogen bonding and then shows how this type of bond is involved in the structure of DNA. The complementary shapes of the base pairs, permitting hydrogen bonding between them, is demonstrated.

The program ends by showing how a complete knowledge of the structure of DNA ebables us to understand how it is possible for the molecule to duplicate itself. The process of DNA replication is shown in animation.

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program twelve

ENZYMES AND DIGESTION

Although all the processes necessary for the maintenance of life occur within the single cell, they can often be performed more efficiently by a multicellular organism. This is because cellular differentiation can occur, certain groups of cells becoming specialized so as to carry on more efficiently a particular task. Because of the efficiency made possible by specialization and the division of labour, increasingly complex multicellular organisms evolved in both the plant and animal kingdom. But this complexity introduces problems of control and co-ordination that are not encountered by simple one-celled organisms. It is therefore necessary, after considering the life of the single cell, and its molecular bases, to proceed to a study of the lives of the complex multicellular organisms.

ENZYME ACTION IN DIGESTION

In mammals, as in all animals, one of the never-ending preoccupations is with food. Program twelve deals with digestion, the problem of releasing the nutrient materials from foodstuffs and absorbing these into the body. Because enzyme action is so important to digestion, opportunity is taken to introduce some basic principles concerning enzymes and their action, using the digestive enzymes as examples.

PHYSICAL AND CHEMICAL BREAKDOWN OF FOODSTUFFS

After establishing the basic anatomy of the digestive tract, the physical breakdown of foodstuffs is considered in its various stages. The role of the teeth, salivary glands, tongue, taste pits and stomach is considered. It is then shown why physical breakdown is not, in itself, enough and that chemical breakdown must also occur so macromolecules are broken into units small enough to diffuse through the semi-permeable membranes lining the intestine. The basic chemical structure of the three principal macromolecules in foodstuffs is then considered, polysaccharides, proteins and lipids. The hydrolysis of each of them in the digestive tract is discussed. The lipids are dealt with first and the vital role of the emulsifying agents of the bile described. Polysaccharides and then proteins are considered, and the sources and role of the hydrolytic enzymes discussed. Animation is used to explain the role of the digestive hormones in co-ordinating the digestive process. The highly specific nature of enzyme action is referred to.

The final sections of the program deal with absorbtion and the movement of material through the digestive tract.

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program thirteen

MUSCLES AND MOVEMENT

HOW MOVEMENT IS EFFECTED

Movement is a property that we associate almost instinctively with life. Program thirteen discusses the question of how movement is effected by mammals.

The first topic discussed is the relation between the muscles and the bones of the skeleton. Antagonistic muscle pairs are then described and their action illustrated. The way in which bones, muscles and joints function as leverage systems is illustated.

HISTOLOGY OF MUSCLE

The program continues with a description of the histology of muscle, first on the light, and then on the electron microscopic level. The ability of muscle to contract must be based on molecular events within the muscle fibre. The fibrous proteins of skeletal muscle are therefore described. It is known that the addition of ATP brings about an interaction between the two different kinds of protein, actin and myosin, in muscle fibre.

The remainder of the program is an interview with Dr. H. E. Huxley, of Cambridge University. Dr. Huxley is a leading expert in the field of the ultrastructure of muscle and the mechanism of its contraction. By means of diagrams and electron micrographs he explains what is known about the ultra-structure of skeletal muscle and current theories regarding its contraction.

program fourteen

NERVES AND NERVE IMPULSES

COORDINATION AND CONTROL

In a multicellular animal that must move from place to place, the problem of co-ordination and control is of major importance. One method of accomplishing this is by means of a nervous system. Program fourteen deals with the question of nervous control. It concentrates on the nature of the nerve itself and on the impulse that passes along it.

NERVES, NERVE FIBRE AND HOW THEY FUNCTION

A large group of prominent nerve physiologists from all over the world gather each summer at the Marine Biology Research Station, Wood's Hole, Massachusetts together with biologists in other disciplines, to continue their research and consult with their colleagues under informal circumstances. Most of this program is a series of interviews with some of these nerve physiologists, who talk about their work and the experiments they are performing. These interviews are arranged so that there emerges a picture of what nerves and nerve fibres are and of how they function. We see the giant axon of the squid being dissected and prepared for studies on the propagation of the nerve impulse along it. The electrical events and the flow of ions through the axon membrane that accompany the transmission of the impulse are described. The means by which impulses travel from one cell to another via synapses, are referred to. The role of acetylcholine in altering the permeability of the axon membrane so as to permit the passage of the impulse, and the role of the enzyme cholinesterase in destroying this material after the passage of the impulse are discussed.

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program fifteen

HORMONES AND CHEMICAL CONTROL

RAPID RESPONSES TO SUDDEN CHANGES

The nervous system evolved in response to the need in the higher animals for a rapid co-ordinated response to sudden changes in the environment. An older and more basic form of control however exists side by side with the nervous system. This is a system of co-ordination involving the use of chemical signalling substances called hormones that diffuse through the body and bring about a slower more prolonged response than that to the nervous system. Program fifteen attempts to establish some of the basic principles involved in this chemical control of the animal body.

HORMONE IMBALANCE

The program begins by showing some of the effects of hormone imbalance in humans. The hormone-producing areas of the body are designated and a description in general terms of hormone action follows. The chemical nature of hormones is briefly discussed and consideration is given to some chemotaxic reactions of unicellular animals, with the suggestion that these represent a rudimentary form of chemical control from which that of the higher multicellular animals might have evolved.

INSULIN

The program then goes into a more detailed consideration of one particular hormone, insulin. Its production in the Islet tissue of the pancreas and its effect on metabolism are described. An interview with the co-discoverer of insulin, Dr. Charles Best, of the University of Toronto, is then presented. Dr. Best outlines the way in which the endocrine function of the pancreas was established, its effect on the individual cell and some of the major problems still to be solved in connection with insulin.

To show that insulin is a metabolic regulator in many classes of animals other than mammals, an account is given of its role in fish and how the special organization of the Islet tissue in certain fish permits experiments that cannot be performed on other animals.

REGULATORY FUNCTIONS

The program concludes with a brief survey of some of the regulatory functions performed by chemical messengers in both plants and animals.

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program sixteen

HOW PLANTS LIFT WATER

Having considered some aspects of the life of a multicellular animal, we next turn to the life of the flowering plant. Equally complex in many respects, the higher plants have evolved a way of life that is based on completely different principles from those regulating animal physiology, even though there is an underlying unity in the problems that must be solved.

TRANSPIRATION

One of the most intriguing questions in plant physiology is the problem of water movement. How is the water absorbed, what forces are responsible for lifting it through the tremendous heights encountered in some trees, why is the water needed in such large amounts? Program sixteen attempts to answer some of these questions.

The first point established is that leaves are exposed to much more radiant energy than they can possibly use and that the evaporation of water from their interior surfaces may serve the useful purpose of dissipating some of this excess radiant energy. The role of the stomata in regulating the evaporation or transpiration of water is described. Reference is made to the amounts of water transpired by different kinds of plants.

WATER MOVEMENT THEORIES

The question is raised of where this water comes from. This leads into a consideration of soil and capillary water and the role of the root hairs in absorbing it by osmosis. By reference to the anatomy of vascular plants, the pathway of water through the plant is demonstrated. Different theories as to how the water moves through the xylem columns are then advanced, and the evidence for and against them considered.

Out of this consideration of rival theories, a description of the leaf-pull or cohesion theory emerges. Experimental evidence supporting it is presented and the program ends with a brief reference to the plant growth system as it is related to water movement.

program seventeen

HOW PLANTS REPRODUCE

THE FLOWER

The reproduction of the flowering plant, like that of any other organism, is based on the division of cells. The types of cell division involved in plant reproduction, are centered in a special organ, the flower. Program seventeen describes the events upon which the reproduction of the seed-producing plants is based, as they occur, on the cellular level, in the various parts of the flower.

The program begins by describing the primordia within the plant tissue from which the flower buds and later the flowers will develop. The question of what stimulus breaks the dormancy of these primordia and triggers flower development is raised. The role of the photoperiod in this function is discussed, as well as that of temperature and plant hormones or auxins.

POLLEN SACS

After a short consideration of basic flower anatomy, the development of the ovule and of the embryo sac within it is described. Then the development of the pollen sacs and their pollen grains is traced. There is a brief description of pollen release and of the main principles of pollen transfer. The further development of the pollen grain after transfer to the stigma is illustrated and the typical double fertilization of the angiosperm is described.

THE SEED

The program concludes by showing how the seed, with its enclosed embryo, and the fruit develop from the fertilized ovule and ovary.

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program eighteen

SEXUAL REPRODUCTION

Having considered the reproduction of single cells by mitosis, and the reproduction of a typical complex multicellular organism, the next topic to be discussed is that of reproduction in general.

PROMOTING VARIATION

Program eighteen deals with the significance of sexual reproduction in promoting variation, and describes the processes of meiotic cell division and syngamy or fertilization that must accompany it.

The opening scenes outline the evolutionary advantage of sexual over asexual forms of reproduction. Different kinds of gametes are illustrated, and the metamorphosis of rabbit spermatids into spermatozoa is traced in order to illustrate the structure of a typical mammalian sperm cell. The structure of the rabbit egg cell is similarly outlined.

EXTERNAL FERTILIZATION

External fertilization is then considered and the process as it occurs in the sea urchin is outlined by Dr. Leonard Nelson. The necessity of internal fertilization for land-dwelling animals is pointed out. The reproductive tract of the rabbit is dissected in order to illustrate the anatomy of internal fertilization. The penetration of the egg cell of the rabbit by male sperm cells is shown.

EGG PENETRATION

Dr. Arthur and Dr. Laura Colwin then present, by means of animation, the results of their research on the mechanism of egg penetration by the sperm, based on electron microscopic studies of fertilization. The description of fertilization concludes with an explanation of its significance and how it promotes greater variability.

MEIOSIS

The necessity of reduction division or meiosis at some point in the reproductive cycle is then pointed out. A brief description of meiosis follows.

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program nineteen

THE TRANSMISSION OF GENES

MENDELIAN LAWS OF INHERITANCE

The function of reproduction is not merely to produce new individuals, but individuals having the same general characteristics as their parents. To understand the laws governing the transmission of these inherited characteristics from one generation to the next has been one of the major problems of biology. The object of program nineteen is to describe the first steps that were made towards an understanding of this problem. The topic is approached historically by showing how the Mendelian laws of inheritance can be derived from cross-breeding experiments and how these in turn lead to the chromosome theory of inheritance.

The opening sequences explain why the common garden pea is ideally suited for cross-breeding experiments of the type Mendel devised. Mendel's experimental plan is outlined and the typical results of a mono-hybrid cross are shown. The way in which these results support the idea that the somatic cells contain two genes governing the expression of each inherited feature, and that these genes segregate in gamete formation and then pair randomly in fertilization, is explained. The idea of dominance is examined and shown to be of only limited application. Direct evidence for the segregation of genes in the gametes, obtained since Mendel's time, is presented.

The results with dihybrid crosses are then discussed and it is shown how they lead to the idea of unit characters.

CROSS-BREEDING EXPERIMENTS

A brief historical survey of important cytological discoveries concerned with cell division and chromosome behaviour follows. It is then shown how the behaviour of the "hereditary factors" or "genes" as deduced from cross-breeding experiments finds

a perfect concordance in the behaviour of the chromosomes. The problem of locating a given gene on the chromosome is briefly considered and the program concludes by suggesting the further concordance that exists between gene behaviour and that of the DNA of the chromosomes.

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program twenty

THE EXPRESSION OF GENES

To understand something of how genes are transmitted from one generation to the next explains nothing of the nature of the gene or of how it manages to mould the growth of the organism in some particular direction. Program twenty is concerned with these questions, the nature of the gene and how it expresses itself.

After a general introduction setting the problem in perspective, the life cycle of bacteriophage virus is described and used as evidence to support the idea that a particular type of DNA can, within the cell, lead to the synthesis of a specific type of protein.

PROTEIN EFFECT ON CHARACTERISTICS

The case of the bread-mould, Neurospora, is considered, to establish the idea that the presence or absence of a particular protein (an enzyme protein) can profoundly affect the characteristics of an organism. The one-gene-one enzyme theory of Beadle and Tatum is introduced.

DNA/RNA

The question of just how it might be possible for a particular DNA to govern the synthesis of a specific protein, is then considered. This is explained by Dr. Paul Gross of the Massachusetts Institute of Technology, a leading researcher in the field of protein synthesis, particularly in the early stages of embryonic development. Dr. Gross explains the nature of the triplet code of DNA, the synthesis of messenger RNA against the DNA template, the movement of this RNA into the ribosomes, and the way in which transfer RNA, in matching up against specific sections of the messenger RNA molecule, brings amino acids into the correct sequence for incorporation into the polypeptide chains of protein.

PROTEIN-SYNTHESIZING MACHINERY

The program concludes with a short interview in which Dr. Alberto Monroy, of the University of Palermo, in Italy, who is prominent in the same field as Dr. Gross, talks briefly about the problem of how the protein-synthesizing machinery of the cell is switched off and on at appropriate stages of embryonic development.

program twenty-one

POPULATIONS, COMMUNITIES AND SUCCESSION

Thus far in the series we have considered the molecular and cellular basis of life, certain specific aspects of the life of individual multicellular organisms, and the general question of reproduction and heredity. We have perforce only considered the organism in relation to itself. In nature however, living things are parts of huge populations, living together in communities and interacting in complex ways with each other and with the environment. In order then to get a truer picture of what life is we must learn something of these interactions and try to understand some of the general principles that govern the collective lives of individuals living in natural communities.

ECOLOGICAL SUCCESSION

Program twenty-one introduces us to the concepts of population and community and considers the way in which communities gradually alter through the process of ecological succession.

The program begins by considering the great number of different kinds of living things and discussing the idea of species. It shows that species has real validity only in terms of population, and that populations rather than individuals or species, are the natural units of nature.

A TYPICAL COMMUNITY

The idea of a community is then developed, as a number of populations of different kinds of organisms living together in a given area. A southern Ontario marsh is used to illustrate a typical community and there is brief reference to other kinds of natural communities.

ORGANISMS ALTER ENVIRONMENT

The next idea presented is that the organisms within a community by the very fact of their existence, can, in many cases, alter the nature of the environment. This change may be such that it renders the environment less suitable for the life of the existing community, and more suitable for that of another, different, community.

With the concept of ecological succession thus introduced, the program concludes with a description of the different stages of a typical ecological succession. Dr. T. Yarranton, a plant ecologist from Scarborough College, University of Toronto, illustrates in the field the various stages in classic sand dune succession.

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program twenty-two

FOOD CHAINS AND ENERGY FLOW

All living things require energy. We find that the organisms within a community can be classified according to how they obtain this energy. Obtaining energy from the sun are the green plants. They serve as the energy source for herbivorous animals who in

turn supply energy to the carnivores. All supply energy to the scavengers and decomposers of the community. The result is that radiant energy from the sun is channeled in succession through the bodies of many different organisms in the community before being finally dissipated into the environment as heat and organic waste.

ENERGY FLOW

Program twenty-two deals with the physical and biological principles that arise in connection with this flow of energy through a natural community.

A SIMPLE FOOD CHAIN

The first topic in the program is a detailed consideration of a simple food chain. This is used to illustrate the pyramid of numbers concept. The biomass accumulated at each stage of the chain is then presented in terms of the stored chemical energy it contains. It is shown that this stored energy becomes less at each stage of the chain and that consequently a pyramid of energy also exists.

TROPHIC LEVELS

The reasons for this decline in stored energy as we pass from one trophic level to the next are then considered. It is shown that the dissipation of a certain amount of stored energy each time the energy is transferred is a necessary condition of its transfer.

Other types of food chains, and food webs are then introduced and the concept of trophic levels established. The relative efficiency of different types of food chains is then considered, and the implication for human nutrition pointed out.

Some fresh water food chains are demonstrated and it is shown that the same general principles apply.

The program closes by discussing the efficiency of fish and algae production in pond culture, and comparing it with the efficiency of conventional agriculture and discussing the reasons for the difference.

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program twenty-three

THE GROWTH OF POPULATIONS

All organisms reproduce and in general their ability to increase in numbers, their biotic potential, is greatly in excess of the increase that can be tolerated in a stable natural community. This fact has great significance in nature. It is responsible for the particular structure of the community; it is the ultimate mechanism responsible for evolution, and it has great implications in human affairs.

GROWTH AND LIMITATION

Program twenty-three is a general introduction to the principles underlying the growth and limitation of populations.

The opening sections of the program establish the idea of the tremendous biotic potential of organisms. It is pointed out that despite this biotic potential, natural populations generally remain more or less constant, and the reasons for this are explored. Such factors as space limitation, food limitation, predation, migration and the physiological effects of overcrowding are considered.

POPULATION PRESSURE

The work of Malthus is referred to, as first drawing attention to the tendency of populations to overgrow the food supply on which they depend. Population pressure is shown to be a vital factor in accounting for the adaptation of living things to virtually every possible ecological niche, including the varying degrees of social organization found among animals.

The question of human population growth is then introduced. The increase in human population in historical times and the reasons for it are discussed. The program ends by considering some of the implications for the future of this population growth.

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program twenty-four

THE EVIDENCE FOR EVOLUTION

CHARLES DARWIN

Since the dawn of life, at the time of the creation of the first self-duplicating molecule, there has been a steady increase in the variety and complexity of living things. To explain how this diversity has come about has been one of the great challenges to biological science. It was Charles Darwin who first assembled complete and systematic proof of the fact of evolution, of the gradual change through time of one species of organism into another. It was he who realized that the steady tendency of populations to increase, held in check only by the unrelenting pressure of food limitation and the conditions imposed by the environment and predation, could provide the basis for the mechanism by which evolution operated.

The concluding programs deal with evolution, the evidences for it, the mechanism by which it operated and the means by which new species come into being.

SIR GAVIN DE BEER

Program twenty-four presents the classical evidence for the fact of evolution. It takes the form of an extended interview with Sir Gavin de Beer, F.R.S., formerly Director of the British Museum (Natural History) and the author of many works on evolution.

In this talk Sir Gavin outlines some of the classical evidence for evolution much as it presented itself to Darwin. Sequences are interspaced, illustrating the points that Sir Gavin makes.

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program twenty-five

MUTATION, VARIATION AND SELECTION

THEORY OF NATURAL SELECTION

To establish the fact of evolution is one thing, to explain how it comes about is another. The great virtue of Darwin's work was that he not only established the fact of evolution, but suggested the theory of natural selection to account for its operation. Program twenty-five explains the theory of natural selection and shows how inherited variation, the raw material upon which selection acts, is produced.

The first section of the program presents the argument from which the fact of natural selection is deduced. It is shown how natural selection leads to adaptation. It is then explained that a weakness of the theory when it was first presented, was that although it accepted and made use of the fact of inherited variation, it could offer no explanation of how this variation was produced.

VARIATION AND THE MOLECULAR BASIS OF MUTATION

The next section shows how, in the light of modern knowledge, such variation is produced. The way in which sexual reproduction leads to the constant re-grouping of genes is discussed. The mechanism of crossing over is described and its significance pointed out. The molecular basis of mutation is explained and it is shown how a minor change in the DNA of the chromosones can lead to a major change in the nature of the protein synthesized. The program ends by considering the role of radiation as a major source of mutation.

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program twenty-six

HOW NEW SPECIES ARE FORMED

SPECIATION

The final program in the series considers the question of speciation, how new kinds of living things are produced. At the first creation of life there were only a very few different kinds of living systems. They now number upwards of two million. Natural selection explains how living things are modified in the course of time, but it does not, in itself, explain why the number of different kinds of living things is constantly increasing.

PHYLETIC EVOLUTION

Program twenty-six attempts to show some of the ways in which this comes about. The first section of the program deals with phyletic evolution; the creation of new species by the gradual modification of pre-existing species. The process is illustrated by reference to the evolution of the heart-urchin, micraster, the ammonites and the horse. The reasons for the change in the horse from a four-toed browsing animal to a one-toed grazing animal are explained.

AUTOPOLYPLOIDY/ALLOPOLYPLOIDY

The program then passes to a consideration of the way in which new species of plants may be created almost overnight as a result of autopolyploidy or allopolyploidy. The mechanisms of these processes are explained.

The final sections of the program deal with the biological species concept, the presence of inherited variation within a species population, and the role of geographic isolation and natural selection in forming new species from sub-populations of an existing species. As an example, the size cline in puffins and penguins is used, the former to show incipient species formation, the latter to show the ultimate results of selection for size in isolated sub-populations of a species.

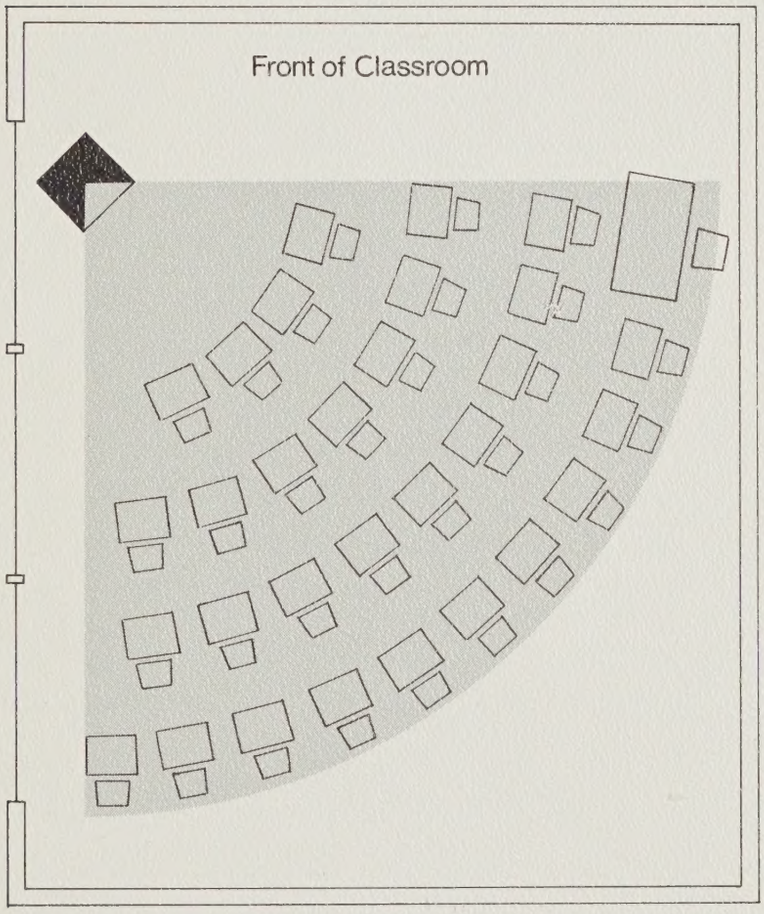
FOR OPTIMUM VIEWING CONDITIONS

1. Review Teacher's Guide well in advance of each telecast.

2. Have the set on and adjusted, sound off, prior to telecast.

3. Assure student comfort
   - — located for best viewing
   - — no glare, reflection on screen
   - — room properly ventilated
   - — suggested materials ready
   - — within maximum of 20′ of the screen

4. Seat yourself where you can observe both the telecast and your students' reactions.



This diagram shows the suggested placement of the television set: